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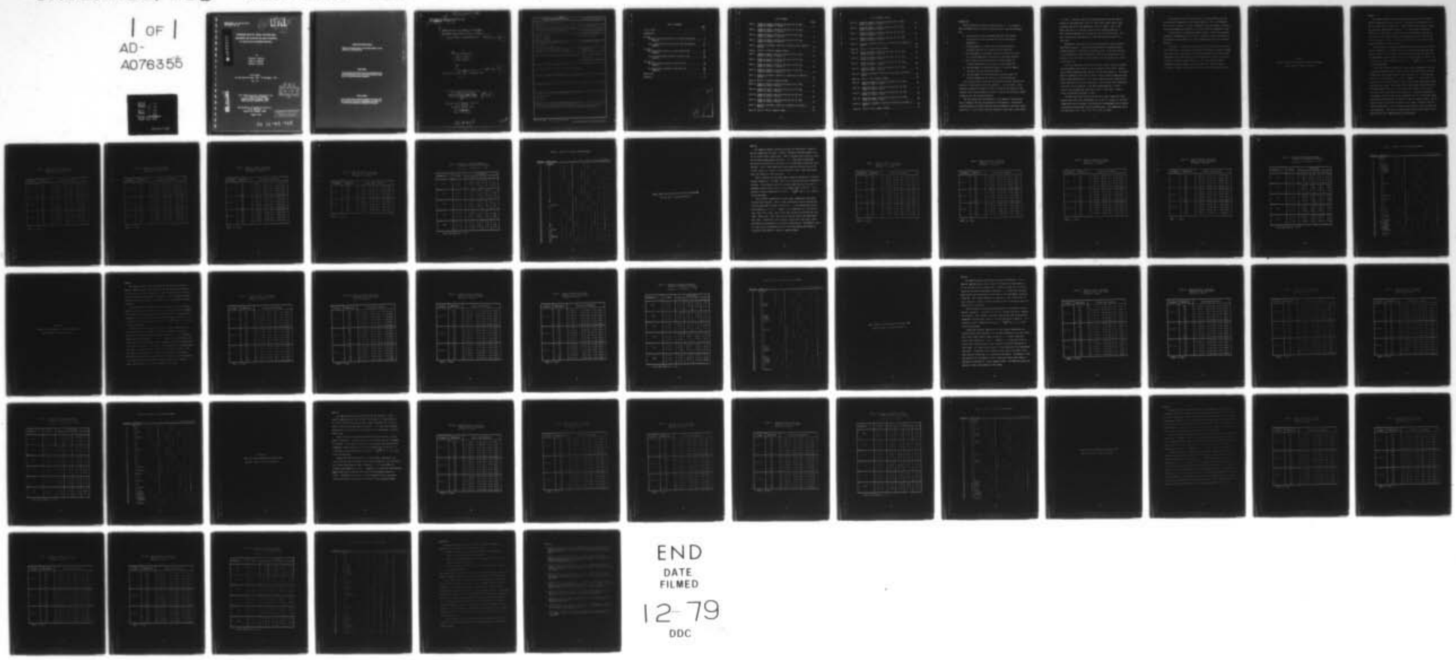

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TEMPERATURE SENSITIVE DYNAMIC CUSHIONING MODEL DEVELOPMENT AND VALIDATION FOR EQUAL THICKNESSES OF SELECTED BULK CUSHIONING MATERIALS

by

Richard M. Wyskida
James D. Johannes
Mickey R. Wilhelm

Final Report
For the Period 8 June, 1978 - 30 September, 1979
Vol. III

This research work was supported by the
U. S. Army Missile Command
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The University of Alabama in Huntsville
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Huntsville, Alabama 35807

August 1979

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This research report involves the development of bulk cushioning models for equal thickness combinations of selected bulk cushioning materials.

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INTRODUCTION

Previous container cushioning research reports [1 - 9], prepared under the MICOM container cushioning research effort, have been concerned with:

1) the acquisition of an experimental data base for selected individual bulk cushioning materials over a wide range of temperatures.
2) the development of a statistically significant parabolic-logrithmic equation for a specific set of conditions.
3) the development of confidence intervals and prediction limits for selected temperature sensitive bulk cushioning materials.
4) the validation of generalized bulk cushioning models for selected temperature sensitive bulk cushioning materials.
5) the development of computerized models for selected temperature sensitive bulk cushioning materials.
6) the development of HP-9815A desk-top calculator models for selected temperature sensitive bulk cushioning materials.

This research report extends the previous work to equal thickness combinations of selected bulk cushioning materials. In this report, a combination or composite of materials refers to identical thicknesses of two different bulk cushioning materials being utilized as the cushioning system, instead of only one cushioning material.

The logic behind the investigation of a two material cushioning system is related to the physical properties of the material. Certain bulk cushioning materials provide excellent shock mitigation at low static stress levels (.03 - .8 psi), while others do likewise at high static stress levels

(> 1.0 psi). Similarly, some bulk cushioning materials provide superior cushions at low temperatures (-65°F to -20°F), while others possess good cushioning ability at high temperatures (100°F to 160°F). Thus, it becomes clear that if a judicious choice of bulk cushioning materials is made, the best properties of each material will be capitalized upon. Perhaps a cushioning system superior to either individual cushion will be identified.

Consequently, three sets of bulk cushioning material were selected for experimental purposes. The bulk cushioning materials selected had been modeled previously as individual cushioning systems. It was felt that previously modeled bulk cushioning materials might be more productive in combination, since individual cushioning models could be compared prior to material selection.

The first combination selected consisted of a 4#/ft.^{3} density polyester type polyurethane foam (Urester 4) for one material, and a 2#/ft.^{3} density cross-linked polyethylene foam (Minicel) for the second material. The second material combination selected was a 4#/ft.^{3} density linear polyethylene foam known as DOW Ethafoam (Etha 4), utilized in combination with the Minicel material identified in the first combination. The third and final combination consisted of like thicknesses of two DOW Ethafoam materials, a 2#/ft.^{3} density linear polyethylene foam known as Etha 2, and a 4#/ft.^{3} density linear polyethylene foam known as Etha 4.

The data acquisition structure was similar to that identified in UAH Research Report No. 159 or MICOM Report No. RL-CR-75-1, Volume III, entitled "Temperature Sensitive Dynamic Cushioning Function Development and Validation for Polyester and Polyether Type Polyurethane Foam." The temperature levels considered were -65°F, -20°F, 20°F, 70°F, 110°F, and 160°F.

The procedures utilized in the analysis of the experimental data have been previously documented in UAH Research Report No. 159, or MICOM Report No. RL-CR-75-1, Volume I, entitled "Temperature Sensitive Dynamic Cushioning Function Development and Validation for Hercules Minicel Thermoplastic Foam."

The validation of the developed composite models follows the procedures documented in MICOM Report No. RL-CR-76-7, Volume I, entitled "Validation of Generalized Cushioning Models for Selected Temperature Sensitive Cushioning Materials."

This report is divided into three basic sections; the first section presents the results of the Urester 4 and Minicel combination cushioning system; the second section concentrates on the Etha 4 and Minicel cushioning system combination; the third and final section presents the results of the Etha 2 and Etha 4 cushioning system combination. All three sections contain appropriate composite dynamic cushioning functions, composite function F-statistics, generalized models, and a discussion of validation statistics.

SECTION I

POLYESTER TYPE POLYURETHANE/CROSS-LINKED POLYETHYLENE

Urester 4(4#/ft.^{3})/Minicel (2#/ft.^{3})

ANALYSIS

The composite dynamic cushioning functions for the Urester 4 + Minicel material combination are given in Tables 1 through 4 for drop heights of 12, 18, 24, and 30 inches, respectively. Table 5 presents the F-statistic values for the various experimental conditions. It is noted that the developed functions are statistically significant for all experimental conditions except seven. Four of these remaining seven equations are very close to the critical value of F. Hence, a slight relaxation of the α level would cause these four equations to be significant.

Table 6 presents the developed general model for the Urester 4 + Minicel material combination. The model consists of a constant term and three independent variables. The container cushioning system designer may substitute the independent variable values directly into the model given in Table 6. It is necessary to adjust temperature utilizing $\theta = \frac{°F + 460}{100}$ and σ_s = psi (100) in the provided model.

Fifty-five different combinations of drop height, temperature, and cushion thickness were evaluated. Twenty-eight of these combinations could not achieve the criteria established for model validation (α = .10 and minimum IDCC G-level value bounded by $\pm$ 1.0 psi.). However, it is noted that in 18 of the cases, a very small number of static stress values were outside of the prediction limit range. These static stress values were at the lower end of the experimental test scale. It would be a rare instance in which such a low static stress level would be encountered in a cushioning system design. Consequently, these 18 cases are not considered to be of a significant nature with regard to validation of the Urester 4 + Minicel composite model. The ten remaining cases are a cause for concern in this model, indicating that this material combination in this configuration may not be as useful as other composite materials. The cushion system designer should utilize caution in the application of this composite material configuration.

Table 1. Composite dynamic cushioning functions for 12" drop height for Urester 4 + Minicel.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-20°	$y = 333.51 - 115.32\ \ell nx + 10.44\ (\ell nx)^2$
	20°	$y = 156.05 - 62.16\ \ell nx + 7.15\ (\ell nx)^2$
	70°	$y = 156.62 - 71.67\ \ell nx + 9.34\ (\ell nx)^2$
	110°	$y = 124.40 - 53.50\ \ell nx + 7.04\ (\ell nx)^2$
	160°	$y = 131.67 - 62.79\ \ell nx + 8.86\ (\ell nx)^2$
2" + 2"	-20°	$y = 280.63 - 97.47\ \ell nx + 8.73\ (\ell nx)^2$
	20°	$y = 103.73 - 38.14\ \ell nx + 3.94\ (\ell nx)^2$
	70°	$y = 83.31 - 33.72\ \ell nx + 3.96\ (\ell nx)^2$
	110°	$y = 60.68 - 23.20\ \ell nx + 2.79\ (\ell nx)^2$
	160°	$y = 70.40 - 30.00\ \ell nx + 3.78\ (\ell nx)^2$
3" + 3"	-20°	$y = 211.76 - 69.29\ \ell nx + 5.84\ (\ell nx)^2$
	20°	$y = 83.80 - 29.72\ \ell nx + 2.92\ (\ell nx)^2$
	70°	$y = 45.21 - 16.58\ \ell nx + 1.88\ (\ell nx)^2$
	110°	$y = 49.39 - 18.59\ \ell nx + 2.10\ (\ell nx)^2$
	160°	$y = 46.30 - 18.42\ \ell nx + 2.22\ (\ell nx)^2$

NOTE: $x = 100\ x$

Table 2. Composite dynamic cushioning functions for 18" drop height for Urester 4 + Minicel.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
	-20°	$y = 344.04 - 126.44 \ln x + 12.59 (\ln x)^2$
	20°	$y = 213.59 - 92.07 \ln x + 11.51 (\ln x)^2$
1" + 1"	70°	$y = 250.81 - 126.12 \ln x + 17.54 (\ln x)^2$
	110°	$y = 205.90 - 100.71 \ln x + 14.43 (\ln x)^2$
	160°	$y = 180.19 - 91.09 \ln x + 13.67 (\ln x)^2$
	-20°	$y = 307.03 - 107.88 \ln x + 9.85 (\ln x)^2$
	20°	$y = 126.99 - 50.57 \ln x + 5.71 (\ln x)^2$
2" + 2"	70°	$y = 127.44 - 56.21 \ln x + 7.03 (\ln x)^2$
	110°	$y = 98.67 - 42.02 \ln x + 5.39 (\ln x)^2$
	160°	$y = 108.21 - 50.62 \ln x + 6.83 (\ln x)^2$
	-20°	$y = 275.92 - 95.37 \ln x + 8.49 (\ln x)^2$
	20°	$y = 95.68 - 34.97 \ln x + 3.62 (\ln x)^2$
3" + 3"	70°	$y = 68.53 - 27.89 \ln x + 3.40 (\ln x)^2$
	110°	$y = 54.39 - 20.22 \ln x + 2.44 (\ln x)^2$
	160°	$y = 67.08 - 29.53 \ln x + 3.83 (\ln x)^2$

NOTE: $x = 100\,x$

Table 3. Composite dynamic cushioning functions for 24" drop height for Urester 4 + Minicel.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-20°	$y = 484.71 - 198.19 \ln x + 21.73 (\ln x)^2$
	20°	$y = 303.57 - 145.97 \ln x + 19.60 (\ln x)^2$
	70°	$y = 388.13 - 207.08 \ln x + 29.40 (\ln x)^2$
	110°	$y = 305.59 - 163.28 \ln x + 24.47 (\ln x)^2$
	160°	$y = 298.71 - 165.03 \ln x + 25.24 (\ln x)^2$
2" + 2"	-20°	$y = 346.64 - 125.43 \ln x + 11.84 (\ln x)^2$
	20°	$y = 147.15 - 61.24 \ln x + 7.30 (\ln x)^2$
	70°	$y = 163.73 - 78.11 \ln x + 10.36 (\ln x)^2$
	110°	$y = 134.98 - 63.56 \ln x + 8.68 (\ln x)^2$
	160°	$y = 140.73 - 69.00 \ln x + 9.64 (\ln x)^2$
3" + 3"	-20°	$y = 335.06 - 117.71 \ln x + 10.64 (\ln x)^2$
	20°	$y = 110.25 - 41.46 \ln x + 4.45 (\ln x)^2$
	70°	$y = 100.38 - 44.38 \ln x + 5.63 (\ln x)^2$
	110°	$y = 76.74 - 32.18 \ln x + 4.19 (\ln x)^2$
	160°	$y = 89.12 - 42.60 \ln x + 5.83 (\ln x)^2$

NOTE: x = 100 x

Table 4. Composite dynamic cushioning functions for 30" drop height for Urester 4 + Minicel.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
2" + 2"	-20°	$y = 397.35 - 151.77 \ln x + 15.15 (\ln x)^2$
	20°	$y = 185.43 - 83.16 \ln x + 10.53 (\ln x)^2$
	70°	$y = 219.70 - 109.42 \ln x + 14.79 (\ln x)^2$
	110°	$y = 168.39 - 80.84 \ln x + 11.28 (\ln x)^2$
	160°	$y = 192.99 - 100.09 \ln x + 14.32 (\ln x)^2$
3" + 3"	-20°	$y = 378.50 - 138.80 \ln x + 13.10 (\ln x)^2$
	20°	$y = 134.40 - 55.17 \ln x + 6.40 (\ln x)^2$
	70°	$y = 136.41 - 63.25 \ln x + 8.19 (\ln x)^2$
	110°	$y = 107.05 - 49.32 \ln x + 6.67 (\ln x)^2$
	160°	$y = 121.86 - 58.48 \ln x + 7.93 (\ln x)^2$

NOTE: $x = 100\ x$

Table 5. Quadratic polynomial regression F-statistics for Urester 4 + Minicel.

$F_{critical}$ = 3.0; Outlier t = 1.66

TEMPERATURE (°F)	THICKNESS	Drop Height			
		12"	18"	24"	30"
-20°	1" + 1"	7.69	5.07	40.99	----
	2" + 2"	13.94	16.89	67.95	13.80
	3" + 3"	7.12	9.44	15.75	32.29
20°	1" + 1"	2.77*	2.61*	2.02*	----
	2" + 2"	5.72	4.13	4.02	1.74*
	3" + 3"	5.02	2.89*	2.75*	2.74*
70°	1" + 1"	12.67	5.84	4.88	----
	2" + 2"	4.80	4.80	3.93	4.27
	3" + 3"	2.12*	3.42	3.16	3.36
110°	1" + 1"	17.84	11.11	6.06	----
	2" + 2"	9.07	13.82	7.65	9.84
	3" + 3"	13.82	3.48	3.98	5.68
160°	1" + 1"	11.61	8.19	5.39	----
	2" + 2"	11.08	4.99	7.52	5.45
	3" + 3"	6.28	11.34	4.20	7.35

* Not Significant at α = 0.10

Table 6. Urester 4 + Minicel Composite Model.

Variable	Coefficient	θ	θ^2	θ^3	$h^{1/2}$	$T^{-1/2}$	$T^{-3/2}$	$(\ln \sigma_s)$	$(\ln \sigma_s)^2$
0	176.96306								
1	0.0	x				x			
2		x				x		x	
3		x				x			x
4		x			x		x		
5		x			x		x	x	
6		x			x		x		x
7		x			x	x			
8		x			x	x		x	
9		x			x	x			x
10			x			x			
11			x			x		x	
12			x			x			x
13			x		x		x		
14			x		x		x	x	
15			x		x		x		x
16			x		x	x			
17			x		x	x		x	
18			x		x	x			x
19				x		x			
20				x		x		x	
21				x		x			x
22				x	x		x		
23				x	x		x	x	
24	0.010282159			x	x		x		x
25	0.0			x	x	x			
26				x	x	x		x	
27				x	x	x			x
28		x					x		
29		x					x	x	
30		x					x		x
31			x				x		
32			x				x	x	
33			x				x		x
34				x			x		
35				x			x	x	
36				x			x		x
37		x							
38	-13.903138	x						x	
39	0.0	x							x
40	0.0		x						
41	0.0		x					x	
42	0.26984519		x						x
43	0.0			x					
44	0.0			x				x	
45	0.0			x					x

CROSS-LINKED POLYETHYLENE/POLYESTER TYPE POLYURETHANE

Minicel (2#/ft.^{3})/Urester 4(4#/ft.^{3})

ANALYSIS

The composite dynamic cushioning functions for the Minicel + Urester 4 material combination are given in Tables 7 through 10 for drop heights of 12, 18, 24, and 30 inches, respectively. Table 11 presents the F-statistic values for the various experimental conditions. It is noted that the developed functions are statistically significant for all experimental conditions except fourteen. Four of these remaining fourteen equations are very close to the critical value of F. Hence, a slight relaxation of the α level would cause these four equations to be significant.

Table 12 presents the developed general model for the Minicel + Urester 4 material combination. The model consists of a constant term and 20 independent variables. The container cushioning system designer may substitute the independent variable values directly into the model given in Table 12. It is necessary to adjust temperature utilizing $\theta = \frac{°F + 460}{100}$ and σ_s = psi (100) in the provided model.

Sixty different combinations of drop height, temperature, and cushion thickness were evaluated. Nine of these combinations could not achieve the criteria established for model validation (α = .10 and minimum IDCC G-level value bounded by $\pm$ 1.0 psi.). However, it is noted that in six of the nine cases, two or less static stress values were outside of the prediction limit range. These static stress values are at the lower end of the experimental test scale. It would be a rare instance in which such a low static stress level would be encountered in a cushioning system design. Consequently, these six cases are not considered to be of a significant nature with regard to validation of the Minicel + Urester 4 composite model.

Table 7. Composite dynamic cushioning functions for 12" drop height for Minicel + Urester 4.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-20°	$y = 241.65 - 81.80 \ln x + 7.47 (\ln x)^2$
	20°	$y = 143.46 - 56.26 \ln x + 6.58 (\ln x)^2$
	70°	$y = 144.14 - 63.89 \ln x + 8.33 (\ln x)^2$
	110°	$y = 136.20 - 61.88 \ln x + 8.33 (\ln x)^2$
	160°	$y = 115.37 - 51.89 \ln x + 7.32 (\ln x)^2$
2" + 2"	-20°	$y = 214.54 - 67.19 \ln x + 5.42 (\ln x)^2$
	20°	$y = 71.97 - 23.18 \ln x + 2.26 (\ln x)^2$
	70°	$y = 71.42 - 27.96 \ln x + 3.33 (\ln x)^2$
	110°	$y = 61.61 - 23.79 \ln x + 2.88 (\ln x)^2$
	160°	$y = 70.61 - 30.22 \ln x + 3.85 (\ln x)^2$
3" + 3"	-20°	$y = 227.34 - 75.46 \ln x + 6.43 (\ln x)^2$
	20°	$y = 69.47 - 24.37 \ln x + 2.43 (\ln x)^2$
	70°	$y = 41.22 - 15.30 \ln x + 1.80 (\ln x)^2$
	110°	$y = 40.15 - 14.43 \ln x + 1.65 (\ln x)^2$
	160°	$y = 43.35 - 16.87 \ln x + 2.07 (\ln x)^2$

NOTE: $x = 100\,x$

Table 8. Composite dynamic cushioning functions for 18" drop height for Minicel + Urester 4.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-20°	$y = 341.24 - 128.68 \ln x + 13.25 (\ln x)^2$
	20°	$y = 238.94 - 109.22 \ln x + 14.11 (\ln x)^2$
	70°	$y = 263.16 - 136.43 \ln x + 19.40 (\ln x)^2$
	110°	$y = 215.40 - 111.08 \ln x + 16.29 (\ln x)^2$
	160°	$y = 189.76 - 96.60 \ln x + 14.67 (\ln x)^2$
2" + 2"	-20°	$y = 349.24 - 128.29 \ln x + 12.22 (\ln x)^2$
	20°	$y = 89.93 - 31.90 \ln x + 3.56 (\ln x)^2$
	70°	$y = 123.65 - 55.79 \ln x + 7.15 (\ln x)^2$
	110°	$y = 102.43 - 45.73 \ln x + 6.02 (\ln x)^2$
	160°	$y = 89.32 - 40.80 \ln x + 5.69 (\ln x)^2$
3" + 3"	-20°	$y = 245.81 - 88.52 \ln x + 7.99 (\ln x)^2$
	20°	$y = 84.36 - 30.25 \ln x + 3.15 (\ln x)^2$
	70°	$y = 56.58 - 23.25 \ln x + 3.00 (\ln x)^2$
	110°	$y = 56.75 - 22.66 \ln x + 2.86 (\ln x)^2$
	160°	$y = 64.30 - 27.56 \ln x + 3.57 (\ln x)^2$

NOTE: $x = 100\,x$

Table 9. Composite dynamic cushioning functions for 24" drop height for Minicel + Urester 4.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-20^0	$y = 407.85 - 164.24 \ln x + 18.24 (\ln x)^2$
	20^0	$y = 340.96 - 162.47 \ln x + 21.58 (\ln x)^2$
	70^0	$y = 339.70 - 183.63 \ln x + 26.98 (\ln x)^2$
	110^0	$y = 332.99 - 185.76 \ln x + 28.13 (\ln x)^2$
	160^0	$y = 273.74 - 149.42 \ln x + 23.49 (\ln x)^2$
2" + 2"	-20^0	$y = 301.44 - 106.72 \ln x + 9.99 (\ln x)^2$
	20^0	$y = 123.60 - 50.33 \ln x + 6.15 (\ln x)^2$
	70^0	$y = 148.46 - 70.74 \ln x + 9.58 (\ln x)^2$
	110^0	$y = 115.60 - 53.47 \ln x + 7.41 (\ln x)^2$
	160^0	$y = 115.44 - 55.49 \ln x + 8.05 (\ln x)^2$
3" + 3"	-20^0	$y = 284.23 - 104.05 \ln x + 9.92 (\ln x)^2$
	20^0	$y = 98.44 - 37.93 \ln x + 4.27 (\ln x)^2$
	70^0	$y = 92.48 - 41.93 \ln x + 5.51 (\ln x)^2$
	110^0	$y = 74.17 - 31.43 \ln x + 4.13 (\ln x)^2$
	160^0	$y = 82.50 - 38.28 \ln x + 5.26 (\ln x)^2$

NOTE: $x = 100\ x$

Table 10. Composite dynamic cushioning functions for 30" drop height for Minicel + Urester 4.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-20^0	$y = 466.15 - 197.31 \ \ell nx + 22.98 (\ell nx)^2$
	20^0	$y = 421.67 - 217.74 \ \ell nx + 30.56 (\ell nx)^2$
	70^0	$y = 411.82 - 227.90 \ \ell nx + 34.48 (\ell nx)^2$
	110^0	$y = 310.55 - 173.33 \ \ell nx + 27.95 (\ell nx)^2$
	160^0	$y = 373.73 - 214.67 \ \ell nx + 34.53 (\ell nx)^2$
2" + 2"	-20^0	$y = 374.73 - 144.32 \ \ell nx + 14.60 (\ell nx)^2$
	20^0	$y = 169.25 - 76.61 \ \ell nx + 10.02 (\ell nx)^2$
	70^0	$y = 201.94 - 101.50 \ \ell nx + 14.07 (\ell nx)^2$
	110^0	$y = 189.82 - 99.36 \ \ell nx + 14.32 (\ell nx)^2$
	160^0	$y = 171.02 - 88.11 \ \ell nx + 12.91 (\ell nx)^2$
3" + 3"	-20^0	$y = 349.51 - 131.69 \ \ell nx + 12.87 (\ell nx)^2$
	20^0	$y = 119.07 - 49.99 \ \ell nx + 6.02 (\ell nx)^2$
	70^0	$y = 108.29 - 51.08 \ \ell nx + 7.01 (\ell nx)^2$
	110^0	$y = 94.19 - 43.24 \ \ell nx + 5.97 (\ell nx)^2$
	160^0	$y = 106.73 - 51.92 \ \ell nx + 7.34 (\ell nx)^2$

NOTE: x = 100 x

Table 11. Quadratic polynomial regression F-statistics for Minicel + Urester 4.

$F_{critical} = 3.0$; Outlier $t = 1.66$

TEMPERATURE (°F)	THICKNESS	Drop Height			
		12"	18"	24"	30"
-20°	1" + 1"	11.99	4.02	5.39	6.74
	2" + 2"	1.55*	42.43	4.81	63.67
	3" + 3"	7.64	11.88	15.18	27.80
20°	1" + 1"	2.00*	4.09	6.38	4.80
	2" + 2"	3.96	1.41*	1.47*	2.66*
	3" + 3"	7.78	4.57	3.40	3.89
70°	1" + 1"	7.48	6.58	9.18	6.06
	2" + 2"	2.21*	5.02	3.33	4.94
	3" + 3"	1.67*	1.29*	2.41*	2.80*
110°	1" + 1"	5.85	7.00	4.16	3.43
	2" + 2"	2.91*	6.30	6.87	3.84
	3" + 3"	2.85*	3.00	2.81*	3.23
160°	1" + 1"	12.30	7.47	9.38	3.27
	2" + 2"	7.20	7.60	8.71	6.68
	3" + 3"	2.42*	6.81	6.90	8.48

* Not Significant at $\alpha = 0.10$

Table 12. Minicel + Urester 4 Composite Model.

Variable	Coefficient	θ	θ^2	θ^3	$h^{1/2}$	$T^{-1/2}$	$T^{-3/2}$	$(\ln a_s)$	$(\ln a_s)^2$
0	2204.5884								
1	0.0	x				x			
2	0.0	x				x		x	
3	0.0	x				x			x
4	73.252522	x			x		x		
5	-39.010025	x			x		x	x	
6	-4.5392164	x			x		x		x
7	5.1754836	x			x	x			
8	-1.3005991	x			x	x		x	
9	0.0	x			x	x			x
10	0.0		x			x			
11	0.0		x			x		x	
12	0.0		x			x			x
13	0.0		x		x		x		
14	0.0		x		x		x	x	
15	3.6620029		x		x		x		x
16	0.0		x		x	x			
17	0.0		x		x	x		x	
18	0.0		x		x	x			x
19	0.0			x		x			
20	0.0			x		x		x	
21	0.0			x		x			x
22	-0.48309006			x	x		x		
23	0.0			x	x		x	x	
24	-0.29548739			x	x		x		x
25	0.0			x	x	x			
26	0.0			x	x	x		x	
27	0.0			x	x	x			x
28	0.0	x					x		
29	118.01099	x					x	x	
30	0.0	x					x		x
31	-83.691243		x				x		
32	0.0		x				x	x	
33	-5.8215625		x				x		x
34	9.3710246			x			x		
35	0.0			x			x	x	
36	0.39998398			x			x		x
37	-725.38749	x							
38	-117.32628	x						x	
39	3.4598770	x							x
40	58.689010		x						
41	36.498087		x					x	
42	-0.58720109		x						x
43	0.0			x					
44	-2.7682574			x				x	
45	0.0			x					x

SECTION II

DOW POLYETHYLENE FOAM/CROSS-LINKED POLYETHYLENE

Dow Etha 4(4#/ft.^{3})/Minicel (2#/ft.^{3})

ANALYSIS

The composite dynamic cushioning functions for the Etha 4 + Minicel material combination are given in Tables 13 through 16 for drop heights of 12, 18, 24, and 30 inches, respectively. Table 17 presents the F-statistic values for the various experimental conditions. It is noted that the developed functions are statistically significant for all experimental conditions except one.

Table 18 presents the developed general model for the Etha 4 + Minicel material combination. The model consists of a constant term and 15 independent variables. The container cushioning system designer may substitute the independent variable values directly into the model given in Table 18. It is necessary to adjust temperature utilizing $\theta = \frac{°F + 460}{100}$ and σ_s = psi (100) in the provided model.

Seventy-two different combinations of drop height, temperature, and cushion thickness were evaluated. Ten of these combinations could not achieve the criteria established for model validation (α = .10 and minimum IDCC G-level value bounded by $\pm$ 1.0 psi.). However, it is noted that in two of the ten cases, only one static stress value was outside of the prediction limit range. This static stress value is at the lower end of the experimental test scale. It would be a rare instance in which such a low static stress level would be encountered in a cushioning system design. Consequently, these two cases are not considered to be of a significant nature with regard to validation of the Etha 4 + Minicel composite model. The remaining eight cases were very close to the prediction limit range.

Table 13. Composite dynamic cushioning functions for 12" drop height for Etha 4 + Minicel.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65°	$y = 311.28 - 95.23 \ln x + 7.70 (\ln x)^2$
	-20°	$y = 261.21 - 76.97 \ln x + 6.02 (\ln x)^2$
	20°	$y = 282.55 - 94.70 \ln x + 8.45 (\ln x)^2$
	70°	$y = 238.24 - 89.90 \ln x + 9.17 (\ln x)^2$
	110°	$y = 199.33 - 78.02 \ln x + 8.37 (\ln x)^2$
	160°	$y = 141.54 - 56.25 \ln x + 6.46 (\ln x)^2$
2" + 2"	-65°	$y = 335.58 - 111.83 \ln x + 9.68 (\ln x)^2$
	-20°	$y = 236.44 - 74.93 \ln x + 6.23 (\ln x)^2$
	20°	$y = 215.49 - 70.53 \ln x + 6.06 (\ln x)^2$
	70°	$y = 188.94 - 68.16 \ln x + 6.49 (\ln x)^2$
	110°	$y = 135.30 - 49.35 \ln x + 4.87 (\ln x)^2$
	160°	$y = 108.48 - 40.73 \ln x + 4.23 (\ln x)^2$
3" + 3"	-65°	$y = 270.50 - 86.49 \ln x + 7.15 (\ln x)^2$
	-20°	$y = 250.39 - 82.81 \ln x + 7.10 (\ln x)^2$
	20°	$y = 229.36 - 79.19 \ln x + 7.09 (\ln x)^2$
	70°	$y = 137.26 - 46.35 \ln x + 4.13 (\ln x)^2$
	110°	$y = 100.64 - 34.04 \ln x + 3.09 (\ln x)^2$
	160°	$y = 100.30 - 37.94 \ln x + 3.85 (\ln x)^2$

NOTE: $x = 100\,x$

Table 14. Composite dynamic cushioning functions for 18" drop height for Etha 4 + Minicel.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65°	$y = 374.21 - 120.53 \ln x + 104.75(\ln x)^2$
	-20°	$y = 390.09 - 133.92 \ln x + 12.33(\ln x)^2$
	20°	$y = 327.99 - 115.54 \ln x + 11.09(\ln x)^2$
	70°	$y = 324.23 - 132.78 \ln x + 14.74(\ln x)^2$
	110°	$y = 245.72 - 102.30 \ln x + 11.93(\ln x)^2$
	160°	$y = 183.88 - 79.53 \ln x + 10.06(\ln x)^2$
2" + 2"	-65°	$y = 376.98 - 126.33 \ln x + 11.04(\ln x)^2$
	-20°	$y = 270.48 - 87.56 \ln x + 7.50(\ln x)^2$
	20°	$y = 268.26 - 92.43 \ln x + 8.40(\ln x)^2$
	70°	$y = 219.23 - 80.78 \ln x + 7.97(\ln x)^2$
	110°	$y = 153.14 - 56.56 \ln x + 5.79(\ln x)^2$
	160°	$y = 113.59 - 42.47 \ln x + 4.57(\ln x)^2$
3" + 3"	-65°	$y = 337.34 - 115.48 \ln x + 10.26(\ln x)^2$
	-20°	$y = 305.41 - 104.22 \ln x + 9.21(\ln x)^2$
	20°	$y = 253.29 - 88.40 \ln x + 8.04(\ln x)^2$
	70°	$y = 191.70 - 69.45 \ln x + 6.61(\ln x)^2$
	110°	$y = 124.39 - 43.89 \ln x + 4.21(\ln x)^2$
	160°	$y = 116.35 - 44.28 \ln x + 4.59(\ln x)^2$

NOTE: x = 100 x

Table 15. Composite dynamic cushioning functions for 24" drop height for Etha 4 + Minicel.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65°	$y = 490.73 - 172.37 \ln x + 16.35 (\ln x)^2$
	-20°	$y = 435.28 - 157.66 \ln x + 15.63 (\ln x)^2$
	20°	$y = 372.94 - 138.67 \ln x + 14.19 (\ln x)^2$
	70°	$y = 399.90 - 175.73 \ln x + 20.82 (\ln x)^2$
	110°	$y = 320.73 - 143.50 \ln x + 17.74 (\ln x)^2$
	160°	$y = 231.16 - 106.89 \ln x + 14.44 (\ln x)^2$
2" + 2"	-65°	$y = 311.02 - 96.83 \ln x + 8.03 (\ln x)^2$
	-20°	$y = 322.48 - 106.88 \ln x + 9.37 (\ln x)^2$
	20°	$y = 331.32 - 118.82 \ln x + 11.20 (\ln x)^2$
	70°	$y = 245.98 - 93.98 \ln x + 9.68 (\ln x)^2$
	110°	$y = 172.96 - 65.91 \ln x + 7.00 (\ln x)^2$
	160°	$y = 140.05 - 56.15 \ln x + 6.48 (\ln x)^2$
3" + 3"	-65°	$y = 327.50 - 107.49 \ln x + 9.22 (\ln x)^2$
	-20°	$y = 325.42 - 111.11 \ln x + 9.86 (\ln x)^2$
	20°	$y = 295.43 - 104.22 \ln x + 9.57 (\ln x)^2$
	70°	$y = 189.83 - 68.26 \ln x + 6.57 (\ln x)^2$
	110°	$y = 149.64 - 54.64 \ln x + 5.44 (\ln x)^2$
	160°	$y = 112.26 - 42.47 \ln x + 4.53 (\ln x)^2$

NOTE: x = 100 x

Table 16. Composite dynamic cushioning functions for 30" drop height for Etha 4 + Minicel.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65°	$y = 480.70 - 173.55 \ln x + 17.25 (\ln x)^2$
	-20°	$y = 453.82 - 170.29 \ln x + 17.73 (\ln x)^2$
	20°	$y = 487.77 - 193.83 \ln x + 20.85 (\ln x)^2$
	70°	$y = 478.79 - 223.02 \ln x + 27.81 (\ln x)^2$
	110°	$y = 350.17 - 163.80 \ln x + 21.35 (\ln x)^2$
	160°	$y = 296.52 - 145.74 \ln x + 20.38 (\ln x)^2$
2" + 2"	-65°	$y = 445.32 - 152.15 \ln x + 13.66 (\ln x)^2$
	-20°	$y = 371.88 - 126.48 \ln x + 11.42 (\ln x)^2$
	20°	$y = 390.69 - 142.86 \ln x + 137.10 (\ln x)^2$
	70°	$y = 258.87 - 101.87 \ln x + 10.92 (\ln x)^2$
	110°	$y = 192.71 - 76.01 \ln x + 8.47 (\ln x)^2$
	160°	$y = 159.21 - 66.14 \ln x + 7.97 (\ln x)^2$
3" + 3"	-65°	$y = 342.15 - 110.90 \ln x + 9.44 (\ln x)^2$
	-20°	$y = 345.59 - 117.33 \ln x + 10.39 (\ln x)^2$
	20°	$y = 315.88 - 113.57 \ln x + 10.66 (\ln x)^2$
	70°	$y = 234.83 - 87.47 \ln x + 8.67 (\ln x)^2$
	110°	$y = 159.45 - 59.62 \ln x + 6.14 (\ln x)^2$
	160°	$y = 129.67 - 50.85 \ln x + 5.63 (\ln x)^2$

NOTE: x = 100 x

Table 17. Quadratic polynomial regression F-statistics for Etha 4 + Minicel.

$F_{critical}$ = 3.0; Outlier t = 1.66

TEMPERATURE (°F)	THICKNESS	Drop Height			
		12"	18"	24"	30"
-65°	1" + 1"	5.20	22.49	9.47	7.08
	2" + 2"	15.35	11.92	10.48	6.71
	3" + 3"	5.67	8.27	30.76	25.18
-20°	1" + 1"	1.42*	31.98	11.50	6.33
	2" + 2"	17.24	10.77	6.64	9.31
	3" + 3"	21.65	11.45	7.35	12.86
20°	1" + 1"	45.67	17.77	10.22	22.55
	2" + 2"	15.93	8.87	7.91	11.49
	3" + 3"	13.60	11.74	6.47	4.23
70°	1" + 1"	36.89	51.66	12.73	12.99
	2" + 2"	7.52	12.60	26.55	21.34
	3" + 3"	16.98	5.76	13.19	14.33
110°	1" + 1"	21.65	10.40	9.62	3.70
	2" + 2"	25.58	103.72	31.03	13.80
	3" + 3"	8.49	23.16	72.00	97.95
160°	1" + 1"	23.79	8.43	10.01	5.70
	2" + 2"	32.54	46.82	21.10	16.82
	3" + 3"	25.57	22.97	54.19	28.94

* Not Significant at α = 0.10

Table 18. Etha 4 + Minicel Composite Model.

Variable	Coefficient	θ	θ^2	θ^3	$h^{1/2}$	$T^{-1/2}$	$T^{-3/2}$	$(\ln \sigma_s)$	$(\ln \alpha_s)^2$
0	338.68941								
1	0.0	x				x			
2	0.0	x				x		x	
3	0.0	x				x			x
4	0.0	x			x		x		
5	0.0	x			x		x	x	
6	0.0	x			x		x		x
7	32.614392	x			x	x			
8	-5.0961467	x			x	x		x	
9	0.0	x			x	x			x
10	0.0		x			x			
11	0.0		x			x		x	
12	0.0		x			x			x
13	0.0		x		x		x		
14	-3.6993450		x		x		x	x	
15	0.63438176		x		x		x		x
16	-4.3129470		x		x	x			
17	0.58519131		x		x	x		x	
18	0.0		x		x	x			x
19	0.0			x		x			
20	0.0			x		x		x	
21	0.0			x		x			x
22	0.85493419			x	x		x		
23	0.0			x	x		x	x	
24	0.0			x	x		x		x
25	0.0			x	x	x			
26	0.0			x	x	x		x	
27	0.0			x	x	x			x
28	0.0	x					x		
29	0.0	x					x	x	
30	0.0	x					x		x
31	0.0		x				x		
32	10.660799		x				x	x	
33	-1.8236532		x				x		x
34	-2.4597742			x			x		
35	0.0			x			x	x	
36	0.0			x			x		x
37	0.0	x							
38	53.449983	x						x	
39	3.1497049	x							x
40	-8.8143942		x						
41	8.6115005		x					x	
42	0.0		x						x
43	0.0			x					
44	0.0			x				x	
45	-0.078832109			x					x

CROSS-LINKED POLYETHYLENE/DOW POLYETHYLENE FOAM

Minicel (2#/ft.^{3})/Dow Etha 4(4#/ft.^{3})

ANALYSIS

The composite dynamic cushioning functions for the Minicel + Etha 4 material combination are given in Tables 19 through 22 for drop heights of 12, 18, 24, and 30 inches, respectively. Table 23 presents the F-statistic values for the various experimental conditions. It is noted that the developed functions are statistically significant for all experimental conditions except two. One of these remaining two equations is very close to the critical value of F. Hence, a slight relaxation of the α level would cause this equation to be significant.

Table 24 presents the developed general model for the Minicel + Etha 4 material combination. The model consists of a constant term and 15 independent variables. The container cushioning system designer may substitute the independent variable values directly into the model given in Table 24. It is necessary to adjust temperature utilizing $\theta = \frac{°F + 460}{100}$ and σ_s = psi (100) in the provided model.

Seventy-two different combinations of drop height, temperature, and cushion thickness were evaluated. Ten of these combinations could not achieve the criteria established for model validation (α = .10 and minimum IDCC G-level value bounded by $\pm$ 1.0 psi.). However, it is noted that in two of the ten cases, only one static stress value was outside of the prediction limit range. This static stress value is at the lower end of the experimental test scale. It would be a rare instance in which such a low static stress level would be encountered in a cushioning system design. Consequently, these two cases are not considered to be of a significant nature with regard to validation of the Minicel + Etha 4 composite model. The remaining eight cases were very close to the prediction limit range.

Table 19. Composite dynamic cushioning functions for 12" drop height for Minicel + Etha 4.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65°	$y = 332.53 - 101.48 \ln x + 8.19 (\ln x)^2$
	-20°	$y = 286.99 - 88.61 \ln x + 7.30 (\ln x)^2$
	20°	$y = 296.18 - 98.82 \ln x + 8.86 (\ln x)^2$
	70°	$y = 213.86 - 79.95 \ln x + 8.37 (\ln x)^2$
	110°	$y = 169.75 - 64.94 \ln x + 7.21 (\ln x)^2$
	160°	$y = 131.85 - 50.38 \ln x + 5.99 (\ln x)^2$
2" + 2"	-65°	$y = 302.59 - 93.55 \ln x + 7.53 (\ln x)^2$
	-20°	$y = 239.13 - 73.21 \ln x + 5.85 (\ln x)^2$
	20°	$y = 208.03 - 66.30 \ln x + 5.59 (\ln x)^2$
	70°	$y = 133.85 - 42.84 \ln x + 3.78 (\ln x)^2$
	110°	$y = 124.89 - 43.66 \ln x + 4.24 (\ln x)^2$
	160°	$y = 93.74 - 31.80 \ln x + 3.16 (\ln x)^2$
3" + 3"	-65°	$y = 246.72 - 71.62 \ln x + 5.27 (\ln x)^2$
	-20°	$y = 252.40 - 80.45 \ln x + 6.58 (\ln x)^2$
	20°	$y = 224.77 - 75.92 \ln x + 6.63 (\ln x)^2$
	70°	$y = 158.63 - 55.98 \ln x + 5.21 (\ln x)^2$
	110°	$y = 112.14 - 39.10 \ln x + 3.71 (\ln x)^2$
	160°	$y = 105.91 - 39.19 \ln x + 3.93 (\ln x)^2$

NOTE: $x = 100\,x$

Table 20. Composite dynamic cushioning functions for 18" drop height for Minicel + Etha 4.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65°	$y = 442.57 - 147.09 \ln x + 13.09 (\ln x)^2$
	-20°	$y = 347.67 - 114.29 \ln x + 10.28 (\ln x)^2$
	20°	$y = 302.22 - 103.51 \ln x + 9.94 (\ln x)^2$
	70°	$y = 301.35 - 126.18 \ln x + 14.74 (\ln x)^2$
	110°	$y = 240.00 - 100.60 \ln x + 12.23 (\ln x)^2$
	160°	$y = 192.89 - 84.29 \ln x + 11.25 (\ln x)^2$
2" + 2"	-65°	$y = 344.61 - 110.30 \ln x + 9.27 (\ln x)^2$
	-20°	$y = 283.58 - 90.70 \ln x + 7.66 (\ln x)^2$
	20°	$y = 235.36 - 76.27 \ln x + 6.63 (\ln x)^2$
	70°	$y = 203.52 - 73.91 \ln x + 7.31 (\ln x)^2$
	110°	$y = 153.45 - 56.17 \ln x + 5.80 (\ln x)^2$
	160°	$y = 113.50 - 40.67 \ln x + 4.40 (\ln x)^2$
3" + 3"	-65°	$y = 297.52 - 91.43 \ln x + 7.21 (\ln x)^2$
	-20°	$y = 295.16 - 96.95 \ln x + 8.22 (\ln x)^2$
	20°	$y = 227.24 - 75.35 \ln x + 6.54 (\ln x)^2$
	70°	$y = 150.33 - 51.78 \ln x + 4.81 (\ln x)^2$
	110°	$y = 133.25 - 48.44 \ln x + 4.82 (\ln x)^2$
	160°	$y = 103.07 - 37.09 \ln x + 3.82 (\ln x)^2$

NOTE: x = 100 x

Table 21. Composite dynamic cushioning functions for 24" drop height for Minicel + Etha 4.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65°	$y = 571.18 - 202.37 \ln x + 19.13 (\ln x)^2$
	-20°	$y = 370.42 - 126.08 \ln x + 12.09 (\ln x)^2$
	20°	$y = 342.18 - 124.25 \ln x + 12.90 (\ln x)^2$
	70°	$y = 381.99 - 168.52 \ln x + 20.66 (\ln x)^2$
	110°	$y = 300.75 - 134.80 \ln x + 17.46 (\ln x)^2$
	160°	$y = 231.86 - 107.24 \ln x + 15.24 (\ln x)^2$
2" + 2"	-65°	$y = 362.05 - 116.19 \ln x + 9.88 (\ln x)^2$
	-20°	$y = 291.75 - 91.83 \ln x + 7.72 (\ln x)^2$
	20°	$y = 284.43 - 95.98 \ln x + 8.68 (\ln x)^2$
	70°	$y = 221.72 - 82.54 \ln x + 8.53 (\ln x)^2$
	110°	$y = 189.60 - 72.09 \ln x + 7.76 (\ln x)^2$
	160°	$y = 151.06 - 59.19 \ln x + 6.89 (\ln x)^2$
3" + 3"	-65°	$y = 324.96 - 101.68 \ln x + 8.23 (\ln x)^2$
	-20°	$y = 284.42 - 94.17 \ln x + 8.13 (\ln x)^2$
	20°	$y = 280.16 - 96.96 \ln x + 8.75 (\ln x)^2$
	70°	$y = 187.23 - 68.43 \ln x + 6.75 (\ln x)^2$
	110°	$y = 149.58 - 56.26 \ln x + 5.85 (\ln x)^2$
	160°	$y = 123.82 - 46.13 \ln x + 4.92 (\ln x)^2$

NOTE: x = 100 x

Table 22. Composite dynamic cushioning functions for 30" drop height for Minicel + Etha 4.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65^{0}	$y = 543.41 - 191.73 \ln x + 18.62 (\ln x)^2$
	-20^{0}	$y = 470.97 - 174.53 \ln x + 18.12 (\ln x)^2$
	20^{0}	$y = 434.20 - 170.20 \ln x + 18.75 (\ln x)^2$
	70^{0}	$y = 438.36 - 201.18 \ln x + 25.77 (\ln x)^2$
	110^{0}	$y = 341.69 - 163.44 \ln x + 22.66 (\ln x)^2$
	160^{0}	$y = 337.99 - 173.79 \ln x + 25.72 (\ln x)^2$
2" + 2"	-65^{0}	$y = 350.68 - 108.95 \ln x + 9.06 (\ln x)^2$
	-20^{0}	$y = 341.15 - 110.84 \ln x + 9.66 (\ln x)^2$
	20^{0}	$y = 308.84 - 106.37 \ln x + 9.91 (\ln x)^2$
	70^{0}	$y = 262.95 - 102.63 \ln x + 11.11 (\ln x)^2$
	110^{0}	$y = 215.99 - 86.54 \ln x + 9.84 (\ln x)^2$
	160^{0}	$y = 189.30 - 78.73 \ln x + 9.60 (\ln x)^2$
3" + 3"	-65^{0}	$y = 344.20 - 109.78 \ln x + 9.11 (\ln x)^2$
	-20^{0}	$y = 318.53 - 105.82 \ln x + 9.18 (\ln x)^2$
	20^{0}	$y = 300.33 - 107.32 \ln x + 10.04 (\ln x)^2$
	70^{0}	$y = 194.55 - 72.65 \ln x + 7.43 (\ln x)^2$
	110^{0}	$y = 184.02 - 71.29 \ln x + 7.58 (\ln x)^2$
	160^{0}	$y = 137.21 - 52.97 \ln x + 5.92 (\ln x)^2$

NOTE: $x = 100\,x$

Table 23. Quadratic polynomial regression F-statistics for Minicel + Etha 4.

$F_{critical} = 3.0$; Outlier $t = 1.66$

TEMPERATURE (°F)	THICKNESS	Drop Height			
		12"	18"	24"	30"
-65°	1" + 1"	7.86	9.99	6.04	14.19
	2" + 2"	2.49*	16.16	5.71	7.20
	3" + 3"	8.62	11.22	5.68	16.22
-20°	1" + 1"	9.94	10.27	11.19	18.03
	2" + 2"	2.80*	6.58	8.76	8.09
	3" + 3"	9.13	17.39	13.22	9.36
20°	1" + 1"	27.54	16.53	9.47	35.76
	2" + 2"	9.39	7.89	12.48	12.36
	3" + 3"	17.25	20.57	9.84	6.85
70°	1" + 1"	82.37	54.63	31.77	36.30
	2" + 2"	6.16	19.66	55.82	144.79
	3" + 3"	13.85	61.70	16.93	18.44
110°	1" + 1"	27.69	42.98	21.56	9.89
	2" + 2"	34.97	53.54	28.87	37.74
	3" + 3"	14.54	29.59	19.35	38.15
160°	1" + 1"	17.06	9.36	11.78	7.02
	2" + 2"	6.59	22.73	38.02	30.40
	3" + 3"	15.04	12.14	23.09	32.93

* Not Significant at $\alpha = 0.10$

Table 24. Minicel + Etha 4 Composite Model.

Variable	Coefficient	θ	θ^2	θ^3	$h^{1/2}$	$T^{-1/2}$	$T^{-3/2}$	$(\ln \sigma_s)$	$(\ln \alpha_s)^2$
0	495.97272								
1	0.0	x				x			
2	0.0	x				x		x	
3	0.0	x				x			x
4	30.352322	x			x		x		
5	0.0	x			x		x	x	
6	0.0	x			x		x		x
7	7.2316497	x			x	x			
8	0.0	x			x	x		x	
9	0.0	x			x	x			x
10	0.0		x			x			
11	0.0		x			x		x	
12	0.0		x			x			x
13	0.0		x		x		x		
14	-3.8097934		x		x		x	x	
15	0.0		x		x		x		x
16	0.0		x		x	x			
17	0.0		x		x	x		x	
18	0.0		x		x	x			x
19	0.0			x		x			
20	0.0			x		x		x	
21	0.0			x		x			x
22	0.0			x	x		x		
23	0.0			x	x		x	x	
24	0.11994912			x	x		x		x
25	0.0			x	x	x			
26	-0.055827933			x	x	x		x	
27	0.0			x	x	x			x
28	-88.869467	x					x		
29	0.0	x					x	x	
30	0.0	x					x		x
31	0.0		x				x		
32	11.080006		x				x	x	
33	0.0		x				x		x
34	0.0			x			x		
35	0.0			x			x	x	
36	-0.34449941			x			x		x
37	0.0	x							
38	-63.710830	x						x	
39	1.4256175	x							x
40	-19.209793		x						
41	10.554163		x					x	
42	0.68592748		x						x
43	0.97094918			x					
44	0.0			x				x	
45	-0.14904712			x					x

SECTION III

DOW POLYETHYLENE FOAM/DOW POLYETHYLENE FOAM

Dow Etha 2(2#/ft.^{3})/Dow Etha 4(4#/ft.^{3})

ANALYSIS

The composite dynamic cushioning functions for the Etha 2 + Etha 4 material combination are given in Tables 25 through 28 for drop heights of 12, 18, 24, and 30 inches, respectively. Table 29 presents the F-statistic values for the various experimental conditions. It is noted that the developed functions are statistically significant for all experimental conditions except three.

Table 30 presents the developed general model for the Etha 2 + Etha 4 material combination. The model consists of a constant term and 20 independent variables. The container cushioning system designer may substitute the independent variable values directly into the model given in Table 30. It is necessary to adjust temperature utilizing $\theta = \frac{°F + 460}{100}$ and σ_s = psi (100) in the provided model.

Seventy-two different combinations of drop height, temperature, and cushion thickness were evaluated. One of these combinations could not achieve the criteria established for model validation (α = .10 and minimum IDCC G-level value bounded by $\pm$ 1.0 psi.). However, it is noted that the predicted model values for this case are very close to the acceptable prediction limits. Consequently, this case is not considered to be of a significant nature with regard to validation of the Etha 2 + Etha 4 composite model.

Table 25. Composite dynamic cushioning functions for 12" drop height for Etha 2 + Etha 4.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65°	$y = 336.28 - 101.44\ \ell nx + 8.07\ (\ell nx)^2$
	-20°	$y = 282.84 - 85.42\ \ell nx + 6.93\ (\ell nx)^2$
	20°	$y = 241.38 - 76.55\ \ell nx + 6.62\ (\ell nx)^2$
	70°	$y = 249.41 - 96.36\ \ell nx + 10.10\ (\ell nx)^2$
	110°	$y = 209.50 - 83.67\ \ell nx + 9.18\ (\ell nx)^2$
	160°	$y = 148.77 - 61.38\ \ell nx + 7.25\ (\ell nx)^2$
2" + 2"	-65°	$y = 339.55 - 103.58\ \ell nx + 8.14\ (\ell nx)^2$
	-20°	$y = 267.42 - 81.48\ \ell nx + 6.44\ (\ell nx)^2$
	20°	$y = 226.16 - 71.37\ \ell nx + 5.89\ (\ell nx)^2$
	70°	$y = 174.36 - 61.20\ \ell nx + 5.71\ (\ell nx)^2$
	110°	$y = 133.38 - 47.09\ \ell nx + 4.54\ (\ell nx)^2$
	160°	$y = 112.15 - 42.17\ \ell nx + 4.37\ (\ell nx)^2$
3" + 3"	-65°	$y = 305.85 - 85.80\ \ell nx + 6.08\ (\ell nx)^2$
	-20°	$y = 263.06 - 73.92\ \ell nx + 5.23\ (\ell nx)^2$
	20°	$y = 242.13 - 74.13\ \ell nx + 5.82\ (\ell nx)^2$
	70°	$y = 164.78 - 55.14\ \ell nx + 4.84\ (\ell nx)^2$
	110°	$y = 146.10 - 51.49\ \ell nx + 4.77\ (\ell nx)^2$
	160°	$y = 107.05 - 39.54\ \ell nx + 3.90\ (\ell nx)^2$

NOTE: x = 100 x

Table 26. Composite dynamic cushioning functions for 18" drop height for Etha 2 + Etha 4.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65°	$y = 449.25 - 149.26 \ln x + 13.27 (\ln x)^2$
	-20°	$y = 375.05 - 125.03 \ln x + 11.36 (\ln x)^2$
	20°	$y = 308.05 - 106.25 \ln x + 10.14 (\ln x)^2$
	70°	$y = 330.03 - 138.39 \ln x + 15.68 (\ln x)^2$
	110°	$y = 273.78 - 119.06 \ln x + 14.26 (\ln x)^2$
	160°	$y = 218.87 - 97.97 \ln x + 12.46 (\ln x)^2$
2" + 2"	-65°	$y = 374.32 - 118.79 \ln x + 9.82 (\ln x)^2$
	-20°	$y = 313.87 - 98.56 \ln x + 8.11 (\ln x)^2$
	20°	$y = 284.11 - 94.73 \ln x + 8.28 (\ln x)^2$
	70°	$y = 210.21 - 77.66 \ln x + 7.71 (\ln x)^2$
	110°	$y = 163.77 - 62.21 \ln x + 6.53 (\ln x)^2$
	160°	$y = 141.35 - 56.89 \ln x + 6.37 (\ln x)^2$
3" + 3"	-65°	$y = 361.85 - 105.99 \ln x + 7.92 (\ln x)^2$
	-20°	$y = 339.18 - 103.80 \ln x + 8.16 (\ln x)^2$
	20°	$y = 292.65 - 95.80 \ln x + 8.11 (\ln x)^2$
	70°	$y = 203.89 - 71.36 \ln x + 6.58 (\ln x)^2$
	110°	$y = 175.33 - 64.10 \ln x + 6.21 (\ln x)^2$
	160°	$y = 126.42 - 48.37 \ln x + 5.02 (\ln x)^2$

NOTE: x = 100 x

Table 27. Composite dynamic cushioning functions for 24" drop height for Etha 2 + Etha 4.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
	-65°	$y = 422.66 - 142.36 \ \ell nx + 13.26 (\ell nx)^2$
	-20°	$y = 401.86 - 140.99 \ \ell nx + 13.76 (\ell nx)^2$
1" + 1"	20°	$y = 406.99 - 154.87 \ \ell nx + 16.18 (\ell nx)^2$
	70°	$y = 399.65 - 179.01 \ \ell nx + 21.52 (\ell nx)^2$
	110°	$y = 323.77 - 148.84 \ \ell nx + 18.90 (\ell nx)^2$
	160°	$y = 294.33 - 145.41 \ \ell nx + 19.73 (\ell nx)^2$
	-65°	$y = 405.87 - 129.62 \ \ell nx + 10.84 (\ell nx)^2$
	-20°	$y = 346.94 - 111.23 \ \ell nx + 9.39 (\ell nx)^2$
2" + 2"	20°	$y = 315.16 - 107.79 \ \ell nx + 9.76 (\ell nx)^2$
	70°	$y = 248.29 - 96.01 \ \ell nx + 9.98 (\ell nx)^2$
	110°	$y = 195.84 - 78.99 \ \ell nx + 8.77 (\ell nx)^2$
	160°	$y = 168.41 - 71.83 \ \ell nx + 8.49 (\ell nx)^2$
	-65°	$y = 364.80 - 106.95 \ \ell nx + 8.04 (\ell nx)^2$
	-20°	$y = 339.09 - 104.15 \ \ell nx + 8.26 (\ell nx)^2$
3" + 3"	20°	$y = 297.55 - 96.63 \ \ell nx + 8.15 (\ell nx)^2$
	70°	$y = 214.78 - 76.84 \ \ell nx + 7.30 (\ell nx)^2$
	110°	$y = 190.00 - 71.58 \ \ell nx + 7.22 (\ell nx)^2$
	160°	$y = 143.81 - 56.80 \ \ell nx + 6.14 (\ell nx)^2$

NOTE: x = 100 x

Table 28. Composite dynamic cushioning functions for 30" drop height for Etha 2 + Etha 4.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65°	$y = 488.93 - 170.93 \ln x + 16.53 (\ln x)^2$
	-20°	$y = 452.34 - 167.03 \ln x + 17.22 (\ln x)^2$
	20°	$y = 452.31 - 178.77 \ln x + 19.41 (\ln x)^2$
	70°	$y = 500.17 - 236.14 \ln x + 29.51 (\ln x)^2$
	110°	$y = 419.90 - 205.33 \ln x + 26.96 (\ln x)^2$
	160°	$y = 379.09 - 196.65 \ln x + 27.41 (\ln x)^2$
2" + 2"	-65°	$y = 403.16 - 129.32 \ln x + 10.96 (\ln x)^2$
	-20°	$y = 352.07 - 113.37 \ln x + 9.73 (\ln x)^2$
	20°	$y = 363.26 - 128.60 \ln x + 12.05 (\ln x)^2$
	70°	$y = 274.91 - 109.76 \ln x + 11.86 (\ln x)^2$
	110°	$y = 234.86 - 99.36 \ln x + 11.46 (\ln x)^2$
	160°	$y = 203.49 - 91.35 \ln x + 11.26 (\ln x)^2$
3" + 3"	-65°	$y = 451.73 - 141.29 \ln x + 11.42 (\ln x)^2$
	-20°	$y = 365.21 - 113.00 \ln x + 9.09 (\ln x)^2$
	20°	$y = 297.55 - 96.63 \ln x + 8.15 (\ln x)^2$
	70°	$y = 245.41 - 91.02 \ln x + 8.96 (\ln x)^2$
	110°	$y = 209.72 - 81.37 \ln x + 8.50 (\ln x)^2$
	160°	$y = 167.53 - 68.54 \ln x + 7.64 (\ln x)^2$

NOTE: x = 100 x

Table 29. Quadratic polynomial regression F-statistics for Etha 2 + Etha 4.

$F_{critical} = 3.0$; Outlier $t = 1.66$

TEMPERATURE (°F)	THICKNESS	Drop Height			
		12"	18"	24"	30"
-65°	1" + 1"	7.29	29.44	9.66	7.34
	2" + 2"	4.13	25.13	35.42	24.38
	3" + 3"	2.58*	2.50*	3.91	28.54
-20°	1" + 1"	3.01	8.02	5.35	4.42
	2" + 2"	3.96	9.74	16.33	20.56
	3" + 3"	0.99*	5.46	23.44	8.64
20°	1" + 1"	5.89	6.57	6.74	6.21
	2" + 2"	8.42	40.34	44.09	46.19
	3" + 3"	5.10	19.98	10.16	10.16
70°	1" + 1"	12.02	8.97	6.68	5.73
	2" + 2"	28.96	36.99	19.37	9.39
	3" + 3"	33.52	32.97	31.32	26.27
110°	1" + 1"	26.39	10.30	6.90	5.21
	2" + 2"	18.57	26.39	11.64	12.15
	3" + 3"	33.08	30.37	51.42	54.03
160°	1" + 1"	6.91	5.96	3.00	3.70
	2" + 2"	12.92	13.69	10.68	4.72
	3" + 3"	12.46	23.14	21.35	16.59

* Not Significant at $\alpha = 0.10$

Table 30. Etha 2 + Etha 4 Composite Model.

Variable	Coefficient	θ	θ^2	θ^3	$h^{1/2}$	$T^{-1/2}$	$T^{-3/2}$	$(\ell n\, \sigma_s)$	$(\ell n\, \sigma_s)^2$
0	101.84126								
1	-99.352813	x				x			
2	21.354231	x				x		x	
3	0.0	x				x			x
4	0.0	x			x		x		
5	-1.4437391	x			x		x	x	
6	0.0	x			x		x		x
7	15.056152	x			x	x			
8	-5.1632315	x			x	x		x	
9	0.38916001	x			x	x			x
10	0.0		x			x			
11	0.0		x			x		x	
12	-0.33239932		x			x			x
13	4.3514820		x		x		x		
14	0.0		x		x		x	x	
15	0.0		x		x		x		x
16	0.0		x		x	x			
17	0.0		x		x	x		x	
18	0.0		x		x	x			x
19	0.0			x		x			
20	0.22303519			x		x		x	
21	0.0			x		x			x
22	0.0			x	x		x		
23	-0.59521806			x	x		x	x	
24	0.11350470			x	x		x		x
25	0.0			x	x	x			
26	0.0			x	x	x		x	
27	0.0			x	x	x			x
28	0.0	x					x		
29	0.0	x					x	x	
30	0.0	x					x		x
31	0.0		x				x		
32	0.0		x				x	x	
33	0.0		x				x		x
34	0.0			x			x		
35	1.3420541			x			x	x	
36	-0.30672112			x			x		x
37	291.23260	x							
38	-58.921384	x						x	
39	0.0	x							x
40	-71.524129		x						
41	8.5114836		x					x	
42	0.97569838		x						x
43	4.1622124			x					
44	0.0			x				x	
45	-0.14793199			x					x

DOW POLYETHYLENE FOAM/DOW POLYETHYLENE FOAM

Dow Etha 4(4#/$ft.^3$)/Dow Etha 2(2#/$ft.^3$)

ANALYSIS

The composite dynamic cushioning functions for the Etha 4 + Etha 2 material combination are given in Tables 31 through 34 for drop heights of 12, 18, 24, and 30 inches, respectively. Table 35 presents the F-statistic values for the various experimental conditions. It is noted that the developed functions are statistically significant for all experimental conditions except three. One of the remaining three equations is very close to the critical value of F. Hence, a slight relaxation of the α level would cause this equation to be significant.

Table 36 presents the developed general model for the Etha 4 + Etha 2 material combination. The model consists of a constant term and 20 independent variables. The container cushioning system designer may substitute the independent variable values directly into the model given in Table 36. It is necessary to adjust temperature utilizing $\theta = \frac{°F + 460}{100}$ and σ_s = psi (100) in the provided model.

Seventy-two different combinations of drop height, temperature, and cushion thickness were evaluated. Five of these combinations could not achieve the criteria established for model validation (α = .10 and minimum IDCC G-level value bounded by $\pm$ 1.0 psi.). However, it is noted that in one of the five cases, only one static stress value was outside of the prediction limit range. This static stress value is at the lower end of the experimental test scale. It would be a rare instance in which such a low static stress level would be encountered in a cushioning system design. Consequently, this case is not considered to be of a significant nature with regard to validation of the Etha 4 + Etha 2 composite model. The remaining four cases were very close to the developed prediction limits.

Table 31. Composite dynamic cushioning functions for 12" drop height for Etha 4 + Etha 2.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65°	$y = 351.66 - 104.84 \ln x + 8.18 (\ln x)^2$
	-20°	$y = 340.37 - 111.78 \ln x + 9.71 (\ln x)^2$
	20°	$y = 262.15 - 86.27 \ln x + 7.62 (\ln x)^2$
	70°	$y = 241.37 - 93.37 \ln x + 9.72 (\ln x)^2$
	110°	$y = 214.84 - 87.40 \ln x + 9.59 (\ln x)^2$
	160°	$y = 155.00 - 64.73 \ln x + 7.65 (\ln x)^2$
2" + 2"	-65°	$y = 283.04 - 79.89 \ln x + 5.72 (\ln x)^2$
	-20°	$y = 273.22 - 83.74 \ln x + 6.63 (\ln x)^2$
	20°	$y = 235.45 - 76.15 \ln x + 6.41 (\ln x)^2$
	70°	$y = 164.51 - 58.34 \ln x + 5.48 (\ln x)^2$
	110°	$y = 151.29 - 56.23 \ln x + 5.53 (\ln x)^2$
	160°	$y = 112.36 - 42.93 \ln x + 4.47 (\ln x)^2$
3" + 3"	-65°	$y = 270.84 - 70.67 \ln x + 4.48 (\ln x)^2$
	-20°	$y = 274.62 - 81.28 \ln x + 6.14 (\ln x)^2$
	20°	$y = 245.69 - 76.85 \ln x + 6.15 (\ln x)^2$
	70°	$y = 160.04 - 54.71 \ln x + 4.87 (\ln x)^2$
	110°	$y = 150.80 - 55.16 \ln x + 5.25 (\ln x)^2$
	160°	$y = 102.11 - 37.65 \ln x + 3.69 (\ln x)^2$

NOTE: x = 100 x

Table 32. Composite dynamic cushioning functions for 18" drop height for Etha 4 + Etha 2.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65°	$y = 429.12 - 140.49 \ln x + 12.30 (\ln x)^2$
	-20°	$y = 371.96 - 124.80 \ln x + 11.26 (\ln x)^2$
	20°	$y = 325.18 - 116.49 \ln x + 11.40 (\ln x)^2$
	70°	$y = 315.53 - 132.90 \ln x + 15.09 (\ln x)^2$
	110°	$y = 303.09 - 136.44 \ln x + 16.43 (\ln x)^2$
	160°	$y = 233.69 - 109.51 \ln x + 14.13 (\ln x)^2$
2" + 2"	-65°	$y = 387.97 - 124.54 \ln x + 10.38 (\ln x)^2$
	-20°	$y = 302.31 - 95.15 \ln x + 7.83 (\ln x)^2$
	20°	$y = 267.39 - 88.99 \ln x + 7.78 (\ln x)^2$
	70°	$y = 203.86 - 75.31 \ln x + 7.45 (\ln x)^2$
	110°	$y = 183.76 - 72.00 \ln x + 7.56 (\ln x)^2$
	160°	$y = 137.86 - 55.31 \ln x + 6.14 (\ln x)^2$
3" + 3"	-65°	$y = 364.66 - 106.88 \ln x + 7.96 (\ln x)^2$
	-20°	$y = 314.23 - 95.39 \ln x + 7.43 (\ln x)^2$
	20°	$y = 283.14 - 91.36 \ln x + 7.59 (\ln x)^2$
	70°	$y = 192.81 - 68.33 \ln x + 6.34 (\ln x)^2$
	110°	$y = 169.45 - 63.80 \ln x + 6.32 (\ln x)^2$
	160°	$y = 120.51 - 46.29 \ln x + 4.81 (\ln x)^2$

NOTE: x = 100 x

Table 33. Composite dynamic cushioning functions for 24" drop height for Etha 4 + Etha 2.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65°	$y = 476.67 - 164.46 \ln x + 15.39 (\ln x)^2$
	-20°	$y = 410.59 - 145.43 \ln x + 14.13 (\ln x)^2$
	20°	$y = 399.44 - 153.17 \ln x + 16.00 (\ln x)^2$
	70°	$y = 387.53 - 172.84 \ln x + 20.70 (\ln x)^2$
	110°	$y = 366.12 - 173.39 \ln x + 21.89 (\ln x)^2$
	160°	$y = 285.04 - 139.43 \ln x + 18.73 (\ln x)^2$
2" + 2"	-65°	$y = 445.12 - 147.72 \ln x + 12.76 (\ln x)^2$
	-20°	$y = 351.71 - 116.20 \ln x + 10.09 (\ln x)^2$
	20°	$y = 328.12 - 115.09 \ln x + 10.58 (\ln x)^2$
	70°	$y = 231.40 - 89.82 \ln x + 9.36 (\ln x)^2$
	110°	$y = 213.43 - 87.53 \ln x + 9.65 (\ln x)^2$
	160°	$y = 169.04 - 72.56 \ln x + 8.54 (\ln x)^2$
3" + 3"	-65°	$y = 442.94 - 137.26 \ln x + 10.91 (\ln x)^2$
	-20°	$y = 367.43 - 115.13 \ln x + 9.27 (\ln x)^2$
	20°	$y = 322.21 - 107.75 \ln x + 9.31 (\ln x)^2$
	70°	$y = 202.57 - 72.79 \ln x + 6.92 (\ln x)^2$
	110°	$y = 185.19 - 71.17 \ln x + 7.26 (\ln x)^2$
	160°	$y = 139.90 - 55.55 \ln x + 6.00 (\ln x)^2$

NOTE: x = 100 x

Table 34. Composite dynamic cushioning functions for 30" drop height for Etha 4 + Etha 2.

THICKNESS	TEMPERATURE	DESIGN CURVE EQUATION
1" + 1"	-65°	$y = 573.66 - 211.22 \ln x + 21.01 (\ln x)^2$
	-20°	$y = 471.54 - 176.72 \ln x + 18.18 (\ln x)^2$
	20°	$y = 449.67 - 180.89 \ln x + 19.90 (\ln x)^2$
	70°	$y = 481.13 - 231.20 \ln x + 29.27 (\ln x)^2$
	110°	$y = 447.09 - 224.05 \ln x + 29.44 (\ln x)^2$
	160°	$y = 357.76 - 184.25 \ln x + 25.73 (\ln x)^2$
2" + 2"	-65°	$y = 452.50 - 148.65 \ln x + 12.79 (\ln x)^2$
	-20°	$y = 372.30 - 122.30 \ln x + 10.59 (\ln x)^2$
	20°	$y = 366.11 - 132.04 \ln x + 12.53 (\ln x)^2$
	70°	$y = 264.80 - 107.19 \ln x + 11.64 (\ln x)^2$
	110°	$y = 250.48 - 108.81 \ln x + 12.63 (\ln x)^2$
	160°	$y = 199.46 - 90.58 \ln x + 11.20 (\ln x)^2$
3" + 3"	-65°	$y = 442.63 - 136.53 \ln x + 10.83 (\ln x)^2$
	-20°	$y = 357.75 - 111.20 \ln x + 8.95 (\ln x)^2$
	20°	$y = 351.99 - 120.56 \ln x + 10.70 (\ln x)^2$
	70°	$y = 222.12 - 81.92 \ln x + 8.05 (\ln x)^2$
	110°	$y = 209.89 - 83.15 \ln x + 8.75 (\ln x)^2$
	160°	$y = 144.43 - 59.94 \ln x + 6.82 (\ln x)^2$

NOTE: x = 100 x

Table 35. Quadratic polynomial regression F-statistics for Etha 4 + Etha 2. $F_{critical} = 3.0$; Outlier t = 1.66

TEMPERATURE (°F)	THICKNESS	Drop Height			
		12"	18"	24"	30"
-65°	1" + 1"	4.72	20.64	12.09	18.28
	2" + 2"	1.08*	22.98	42.04	19.51
	3" + 3"	0.63*	2.71*	17.10	11.69
-20°	1" + 1"	26.21	24.34	13.49	13.88
	2" + 2"	3.92	13.85	24.05	16.21
	3" + 3"	9.67	11.43	11.29	8.30
20°	1" + 1"	28.17	13.29	12.09	8.05
	2" + 2"	33.64	41.97	39.85	29.37
	3" + 3"	14.43	33.51	47.36	48.85
70°	1" + 1"	44.14	36.94	14.67	8.40
	2" + 2"	73.33	39.52	45.00	30.73
	3" + 3"	72.97	54.08	39.96	39.30
110°	1" + 1"	73.07	20.06	10.36	9.40
	2" + 2"	37.65	63.22	29.56	21.52
	3" + 3"	34.47	54.77	75.67	25.73
160°	1" + 1"	10.73	7.35	5.59	6.41
	2" + 2"	50.14	20.28	13.55	10.27
	3" + 3"	22.85	37.98	26.58	10.88

* Not Significant at α = 0.10

Table 36. Etha 4 + Etha 2 Composite Model.

Variable	Coefficient	θ	θ^2	θ^3	$h^{1/2}$	$T^{-1/2}$	$T^{-3/2}$	$(\ln \sigma_s)$	$(\ln \sigma_s)^2$
0	364.88310								
1	0.0	x				x			
2	0.0	x				x		x	
3	0.0	x				x			x
4	0.0	x			x		x		
5	0.0	x			x		x	x	
6	0.0	x			x		x		x
7	41.173081	x			x	x			
8	-13.052459	x			x	x		x	
9	1.0084125	x			x	x			x
10	-67.963627		x			x			
11	14.493859		x			x		x	
12	-1.1099463		x			x			x
13	0.0		x		x		x		
14	0.0		x		x		x	x	
15	0.0		x		x		x		x
16	-3.2333637		x		x	x			
17	0.54214573		x		x	x		x	
18	0.0		x		x	x			x
19	7.2069221			x		x			
20	-0.59932201			x		x		x	
21	0.0			x		x			x
22	0.0			x	x		x		
23	-0.19269788			x	x		x	x	
24	0.056610506			x	x		x		x
25	0.0			x	x	x			
26	0.0			x	x	x		x	
27	0.0			x	x	x			x
28	0.0	x					x		
29	0.0	x					x	x	
30	0.0	x					x		x
31	22.870867		x				x		
32	0.0		x				x	x	
33	0.0		x				x		x
34	0.0			x			x		
35	-1.0732096			x			x	x	
36	0.0			x			x		x
37	70.269319	x							
38	-47.453983	x						x	
39	0.0	x							x
40	-15.995790		x						
41	5.7049793		x					x	
42	0.88065089		x						x
43	0.0			x					
44	0.0			x				x	
45	-0.11323733			x					x

CONCLUSIONS

The material contained in this report describes the development of composite cushioning models for equal thicknesses of:

1. 4#/ft.^{3} polyester type polyurethane (Urester 4) combined with 2#/ft.^{3} cross-linked polyethylene (Minicel).
2. 4#/ft.^{3} linear polyethylene (Etha 4) combined with 2#/ft.^{3} cross-linked polyethylene (Minicel).
3. 2#/ft.^{3} linear polyethylene (Etha 2) combined with 4#/ft.^{3} linear polyethylene (Etha 4).

These three material combinations result in six cushioning models, since each material combination may be utilized in two configurations, bottom and top.

The six models have been statistically validated and are available for use on the HP-9815A desktop calculator, or on a FORTRAN language computer. Although all six composite models have been implemented, caution must be exercised when utilizing the Urester 4 + Minicel composite model. Considerable difficulty was experienced in the development of this model which suggests the existence of a natural phenomena which has not been previously encountered. This is perhaps explained through the physical characteristics of the two cushioning materials involved. Urester 4 is much softer than Minicel, and apparently causes the natural phenomena when the Minicel material is located next to the item to be protected, and the Urester 4 material impacts the rigid surface first.

The remaining five composite models perform as expected, and can be utilized in cushioning applications with the same confidence as the single material models.

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